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PROPERTIES OF SEVEN COLOMBIAN WOODS.(U)
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United States
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**Forest
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Research
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Properties of Seven Colombian Woods

Abstract

Woods from abroad are an important raw material to the forest products industries in the United States. A major concern in effective utilization of this resource is the lack of technical information on many species. This report presents the results of an evaluation of the mechanical properties of small, clear specimens of seven Colombian woods. These results are supplemented by information gleaned from world literature concerning other wood properties also important to effective utilization.

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United States Department of Agriculture

Forest Service

Forest Products Laboratory[1]

Research Note FPL-0242

Properties of Seven Colombian Woods.

By

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Introduction

During the peak of U.S. industrial activity in 1973 to 1974, nearly all domestic hardwood species were in short supply. While the supply of hardwood lumber in the United States is currently quite favorable, the long range outlook suggests greater pressure on our hardwood forests. This pressure will develop as we turn increasingly to wood as a renewable resource and as research efforts concentrate on hardwood utilization, including the use of hardwoods in structural applications.

Hardwoods from outside the U.S. are a major resource potential in the U.S. market. This is particularly true for South American species, which represent a major portion of the untapped timber resources of the world. However, the absence of reliable wood property information is a frequent deterrent to the effective utilization of many non-U.S. species.

This report presents the results of an evaluation of the mechanical properties of seven Colombian woods that have been reaching the U.S. market in some quantity. Information concerning other physical properties of these woods important to their effective utilization is summarized from a variety of literature sources. The seven species reported on are:

Common name	**Botanical name**	**Family**
Anime	*Protium* spp.	Burseraceae
Chalviande	*Virola* spp.	Myristicaceae
Cuangare	*Dialyanthera* spp.	Myristicaceae
Pulgande	*Dacryodes* spp.	Burseraceae
Sajo	*Campnosperma panamensis*	Anacardiaceae
Sande	*Brosimum utile*	Moraceae
Tulapueta	*Osteophloeum platyspermum*	Myristicaceae

The common names given are those often used for these species in Colombia. A different common name may be used for the same species from another country and the same name is sometimes used to describe one or more different species. The generic term of the botanical name followed by "spp." indicates that the genera include a number of species that cannot be separated from wood samples alone. Thus, the specific identity of four of the woods evaluated is not known.

Mechanical Properties

Materials and Methods

The material evaluated in this study was collected by Potlatch Forests, Inc. (now Potlatch Corporation). The material originated from the Tumaco, Colombia area as did that for which Mothershead and Markley *(6)*[2] and Lastra et al. *(4)* reported mechanical properties and upon which McMillen and Boone *(5)* conducted kiln-drying studies. These three references report on only three of the seven species: cuangare, sajo, and sande.

Sample material was being processed at the Potlatch R & D laboratory, Lewiston, Idaho, when the company terminated its Columbian interests. The material was then transferred to the Forest Products Laboratory for further processing and property evaluations.

Anime, chalviande, pulgande, and tulapueta planks, representing five trees for each species, had already been processed into 2-1/4-inch sticks about 4 feet long at the Potlatch laboratory. Thirty sticks of each of these four species were received. Half of the sticks arrived partially air dried and were designated for tests at 12 percent moisture content. The other half were for tests in the green moisture condition and were wrapped with polyethylene to retard drying.

Material for cuangare, sajo, and sande arrived in the form of large planks roughly 3 by 12 inches by 14 feet. Five planks of each of the three species were received, each representing one tree. Surface drying was evident, but the interior of the planks remained green. Surface growth of mold fungi was abundant on several planks and machining later revealed some penetration by stain fungi. Although there is evidence that stain fungi can affect mechanical properties, we do not believe there was any significant effect on this sample material.

Six sticks 2-1/2 inches square and 5 feet long were cut from each of the cuangare, sajo, and sande planks (five planks/species) that were designated for mechanical tests. Defects were eliminated in preparation of the sticks, insofar as possible. Three sticks from each group of six were randomly assigned to green testing, three for testing at 12 percent moisture content, for a total of 15

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Italicized numbers in parentheses refer to Literature Cited at the end of report.

tests for each moisture condition and species.

Sticks for all species designated for tests in the green moisture condition were immediately processed into 2-inch standard test specimens and tested according to American Society of Testing and Materials (ASTM) procedures *(1)*. One each of five test specimens was obtained from each stick: static bending, compression parallel to grain, compression perpendicular to grain, shear, and hardness.

Sticks for all species designated for dry testing were kiln dried to approximately 12 percent moisture content using an ultra-mild kiln schedule (maximum temperature of 120° F). Test specimens (for the same five tests as green) were then machined from each stick, brought to equilibrium in a room controlled at 74° F and 65 percent relative humidity (approximately 12 pct EMC), and tested according to standard procedures.

Results

Average mechanical properties, standard deviations, and coefficients of variation for green and air-dry test results are given in table 1. The relatively few specimens evaluated are generally not considered sufficient to provide reliable property estimates for a species. Furthermore, because the collection of sample material apparently was within the logging tributary of one sawmill, the property estimates may not be applicable to the species over their entire growth range.

However, many of the coefficients of variation compare favorably to those for domestic species *(7)*. A notable exception is modulus of elasticity (MOE) in bending. The average coefficient of variation for MOE of U.S. species in the green moisture condition is 22 percent. Those for Colombian woods are consistently lower, ranging from 11.5 percent for sajo to 21.3 percent for cuangare. The coefficients of variation for MOE of dry material are even lower, falling in the range of 6.5 to 16 percent. Other exceptions are the relatively low variation in most properties for sajo and sande and high variation in all properties but MOE for tulapueta.

Mothershead and Markley *(6)* reported mechanical properties for three of the same species evaluated in this study: cuangare, sajo, and sande. Lastra et al. *(4)* also measured specific gravity in the green moisture condition and modulus of rupture (MOR), MOE, shear parallel to grain, side hardness, and specific gravity in the air-dry condition on these same species.

Table 2 compares average results from *(6)* and *(4)* to those obtained in this evaluation. The results of *(6)* compare reasonably well to those reported here for MOR and MOE. Compression perpendicular to grain results from *(6)* are consistently higher in both the green and the air-dry moisture conditions; maximum crushing strength parallel to grain is consistently lower.

Because different test methods *(2)* were used, the results of *(4)* would not necessarily be expected to compare well with either those of *(6)* or those reported here. However, they do provide a basis for an interesting comparison of the results of tests from the DIN *(2)* and ASTM Standards.

When compared to the results reported here, those obtained by the DIN methods *(4)* are consistently lower in shear and MOE; MOR values are consistently higher. With the exception of sande MOR and cuangare MOE, the DIN results relate to those of *(6)* in the same manner.

Differences between the MOR and MOE values obtained by the ASTM and DIN procedures are generally small but consistent enough to suggest the possibility that DIN procedures provide higher MOR but lower MOE values. The DIN procedures also appear to provide lower shear values.

Gilmore and Barefoot *(3)* also evaluated sajo and *Dialyanthera* species. However, the origin of their sample is unknown because they obtained their material from commercial lumber shipments. Thus, we have not included these results in a comparison with sample material known to originate in Colombia.

For convenient reference the species are ranked in ascending order of specific gravity in table 3; mechanical properties, as a result, also are roughly in ascending order. None of the species appear to be unusually weak or strong for their density. The data of Mothershead and Markley *(6)* are not included in the species summaries in table 3 because of reservations expressed by Markley in personal communications. Without elaborating, he indicated that a lot of sample material was less than ideal, necessitating improvisations which apparently affected their results, especially for compression perpendicular to grain and maximum crushing strength parallel to grain.

In table 3, the Colombian species are compared with a native U.S. species of approximately equivalent properties. This table provides a convenient reference basis if a substitute species of similar strength or density is sought. Note, however, that similarities in some properties do not necessarily imply similarities in all properties or that a substitute species will always perform as anticipated in a specific product based upon a similarity of properties. Also, this comparison is not intended as a basis for structural grading under current U.S. practice.

Physical Characteristics

This section presents information concerning the species studied which is summarized from world literature. The material presented includes information on the geographical distribution or botanical growth range of the individual species; a general description of the tree and the wood; information on various physical properties such as drying and shrinkage weight, working characteristics, natural resistance of heartwood to decay, and treatability; and suggested uses for the wood.

In some instances additional mechanical property data are presented. These data were not considered compatible for combination with the results from this study primarily because most of the testing was conducted at laboratories abroad under different standard testing procedures. However, the data are included because they could be useful under specific circumstances.

Note: No information on the physical properties of pulgande and tulapueta was found in the literature.

ANIME (Protium spp.)

Family: Burseraceae

Other Common Names: Copal, Latilla, Pom (Mexico), Alcanfor, Fontole (Honduras), Caraño, Chutra (Panama), Caraño (Colombia), Bálsamo, Tacamahaco (Venezuela), Kurokai (Guyana), Bois encens (French Guiana), Breu branco, Breu preto, Sucuriúba (Brazil).

Distribution: Throughout tropical America but most abundantly represented in the Amazon basin; frequent in the marsh forests of Guyana.

THE TREE

Usually up to 90 feet in height; diameters mostly 16 to 20 inches, sometimes up to 40 inches. Some species with low flat buttresses and fluted boles.

THE WOOD

General Characteristics: Heartwood brown or reddish brown, sometimes with irregularly spaced darker brown lines; not always sharply demarcated from the pale buff to pinkish sapwood. Texture varies from rather fine to fairly coarse; luster rather high; grain straight to very irregular and interlocked; dry specimens without distinctive odor or taste. Silica reported for some species.

Weight: Basic specific gravity (ovendry weight/green volume) varies with species from 0.45 to 0.61; air-dry density 33 to 45 pounds per cubic foot. Basic specific gravity from this study is 0.50 and the weight at 12 percent moisture content is 38 pounds per cubic foot.

Mechanical Properties: (First set of data based on the 2-cm standard, the second set on the 2- inch standard, and the third set on the 1-inch standard.)

Moisture content	Bending strength	Modulus of elasticity	Maximum crushing strength
	Lb/in.^{2}	10^6 lb/in.^{2}	Lb/in.^{2}
Green *(3)**	11,000	1.460	5,280
12 percent	16,850	1.760	9,200
Green *(2)**	9,300	1.510	4,370
12 percent	11,800	1.650	6,960
12 percent *(1)**	15,700	1.860	8,700

*See "Additional Reading" for references.

Janka side hardness at 12 percent moisture content ranged from 720 to 1,280 pounds. Forest Products Laboratory toughness at 12 percent moisture content is 167 inches to pound (5/8- inch specimen).

Drying and Shrinkage: Reports vary from fairly easy to air dry to moderately difficult. Kiln schedule T3-C2 is suggested for 4/4 stock and T3- C1 for 8/4. Shrinkage green to ovendry: radial 4.2 percent; tangential 6.8 percent; volumetric 10.7 percent.

Working Properties: Logs should be debarked prior to sawing to avoid resin accumulation on cutters and equipment. Dry wood works easily and rates fair to good in all operations. Cuts easily into veneers but tends to buckle on drying. Some species abrasive because of silica content.

Durability: Generally reported to have low resistance to attack by decay fungi and vulnerable to dry-wood termites. No appreciable resistance to marine borers.

Preservation: Generally heartwood is reported as difficult to treat with pressure-vacuum systems; sapwood is responsive.

Uses: Furniture, millwork, veneer and plywood, general construction, particleboard, a possible substitute for birch. Incenselike resin obtained from wounds to the bark and marketed as "elemi."

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CHALVIANDE (Virola spp.)

Family: Myristicaceae

Other Comon Names: Banak, Sangre, Palo de sangre (Guatemala, Honduras), Sangredrago (Nicaragua), Fruta dorada (Costa Rica), Miguelarillo (Panama), Sangre de toro (Colombia), Camaticaro (Venezuela), Baboen (Surinam), Bicuiba (Brazil), Cumala (Peru).

Distribution: Varying with species from Belize and Guatemala southward to Venezuela, the Guianas, the Amazon region of northern Brazil, southern Brazil, and, on the Pacific Coast to Peru and Bolivia; common in swamp and marsh forests.

THE TREE

May reach a height of 140 feet with trunk diameters of 60 inches; usually much shorter and only 24 to 36 inches in diameter. Boles are heavily buttressed, cylindrical, and clear for more than two-thirds of total height.

THE WOOD

General Characteristics: On drying and exposure, heartwood becomes a pinkish, golden brown or deep reddish brown; sapwood cream to tan color, not always sharply demarcated. Luster low to medium; texture rather coarse; grain straight; dry specimens without distinctive odor or taste.

Weight: Basic specific gravity (ovendry weight/green volume) varies considerably with species from about 0.36 to 0.61, commonly 0.44; air-dry density 27 to 46 pounds per cubic foot. Basic specific gravity from this study is 0.37 and the weight at 12 percent moisture content is 30 pounds per cubic foot.

Mechanical Properties: (First set of data based on the 2-inch standard, the second set on the 2-cm standard, and the third set on the 1-inch standard.)

Moisture content	Bending strength	Modulus of elasticity	Maximum crushing strength
	Lb/in.²	10^6 lb/in.²	Lb/in.²
Green *(4)**	5,600	1.640	2,390
12 percent	10,950	2.040	5,140
Green *(2)*	6,520	1.380	3,180
12 percent	11,450	1.610	5,950
12 percent *(1)*	7,780	1.280	4,740

*See "Additional Reading" for references.

Janka side hardness for dry material 450 to 640 pounds. Forest Products Laboratory toughness average for green and dry material 61 inches to pound (5/8-inch specimen).

Drying and Shrinkage: Generally reported to be difficult to season with a strong tendency to warp and check as well as collapse and honeycomb; thick stock slow to dry. Kiln schedule T3-C2 suggested for 4/4 stock and T3- C1 for 8/4. Shrinkage green to ovendry: radial 4.6 percent; tangential 8.8 percent; volumetric 13.7 percent.

Working Properties: Works easily with both hand and machine tools and a good finish is obtainable; glues well; cuts well into veneers.

Durability: The wood is not resistant to attack by decay fungi and is very susceptible to attack by termites and other insects. Logs require prompt conversion or water storage to prevent damage by pinhole borers. Bacterial attack resulting in the formation of odoriferous compounds is also reported.

Preservation: The timber is reported to be easily impregnated with preservatives using either pressure-vacuum or open tank systems.

Uses: Veneer and plywood, particle and fiberboard, furniture components, boxes and crates, light construction, general carpentry, millwork. Oil is extracted from seeds of *Virola* and used in soaps and candles.

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CUANGARE *(Dialyanthera spp.)*

Family: Myristicaceae

Other Common Names: Fruta dorado (Costa Rica), Miguelario (Panama), Otoba (Venezuela), Cuangare (Colombia), Coco (Ecuador), Virola (U.S.)

Distribution: Main commercial supply from the species growing in almost pure stands in the Pacific coastal fresh water swamp forest of Colombia and Ecuador. Other species in upland forests of Costa Rica, Panama, and Venezuela.

THE TREE

May reach a height of 100 feet and a trunk diameter of 50 inches; boles are well formed and clear to 50 feet.

THE WOOD

General Characteristics: Pale pinkish-brown, there is no demarcation between sapwood and heartwood. Luster medium to high; grain generally straight; texture variable; without odor or taste.

Weight: Basic specific gravity (ovendry weight/green volume) 0.36; air-dry density 28 pounds per cubic foot.

Mechanical Properties: (2-inch standard.)

Moisture content	Bending strength	Modulus of elasticity	Maximum crushing strength
	Lb/in.^{2}	10^6 lb/in.^{2}	Lb/in.^{2}
12 percent *(1)**	10,400	1.900	—

*See "Additional Reading" for references.

Drying and Shrinkage: Colombian cuangare air seasons and kiln dries readily but material containing "brownheart" or wet streaks tends to collapse and has irregular drying rates. In kiln drying a modified T5-C3 schedule is suggested for 4/4 stock *(3)*. Shrinkage green to ovendry: radial 4.2 percent; tangential 9.4 percent; volumetric 12.0 percent.

Working Properties: Generally machines well if sharp knives are used and dressed with the grain. Easy to nail and glue; takes stain, paint, and clear finishes well.

Durability: Heartwood is nondurable and is susceptible to insect attack. Wood is prone to blue stain and requires rapid extraction and conversion.

Preservation: The wood is rated as moderately easy to preserve with uniform penetration of treating solutions.

Uses: Core stock, moldings, paneling, particleboard, general carpentry, and furniture components.

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SAJO
(Campnosperma panamensis)

Family: Anacardiaceae

Other Common Names: Orey (Costa Rica)

Distribution: Reported in the Atlantic lowlands of northern Panama, adjacent to Costa Rica, and Pacific coastal regions of Colombia; forms almost pure stands in these marshy areas.

THE TREE

Medium-size trees 40 to 60 feet high with bole diameters of 10 to 15 inches, occasionally up to 24 inches; well-formed stems that are often clear to 30 feet.

THE WOOD

General Characteristics: Heartwood white to grayish-buff, sometimes with a yellowish tint; no marked contrast with the sapwood. Somewhat, silvery luster; fine textured; straight grained; distinctive odor when fresh, but without characteristic odor or taste when dry.

Weight: Basic specific gravity (ovendry weight/green volume) 0.33; air-dry density 25 pounds per cubic foot. Basic specific gravity from this study is 0.34 and the weight at 12 percent moisture content is 26 pounds per cubic foot.

Drying and Shrinkage: The lumber air seasons rapidly with little or no tendency to warp or check. Kiln schedule T5- C3 has been suggested for 4/4 stock. A faster schedule has been suggested that can dry this wood to 7 percent moisture content in 6 to 8 days *(2)*. No shrinkage data available.

Working Properties: This is a wood that is easy to saw and machine with ordinary shop tools; holds nails well; and finishes smoothly.

Durability: The wood is not resistant to attack by decay fungi or insects; prone to blue stain.

Preservation: The wood is reported to be easy to treat.

Uses: Boxes and food containers, furniture components, millwork, moldings, plywood, particleboard, fiberboard, pulp and paper products; also suggested for pencil slats.

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SANDE (Brosimum Utile)

Family: Moraceae

Other Common Names: Mastate (Costa Rica), Avichuri (Colombia), Palo de vaca (Venezuela), Amapá doce, Caucho macho (Brazil).

Distribution: Ranges from the Atlantic Coast in Costa Rica southward to Colombia and Ecuador.

THE TREE

The tree attains a height of 80 to 100 feet with an erect trunk about 30 to 45 inches in diameter.

THE WOOD

General Characteristics: Dried there is no distinction between sapwood and heartwood, uniform yellowish white to yellowish brown or light brown. Grain is straight to widely and shallowly interlocked; medium texture; luster high. Odorless and tasteless.

Weight: Basic specific gravity (ovendry weight/green volume) ranges from 0.35 to 0.50 for the Utile group. Air-dry density averages about 24 to 38 pounds per cubic foot. Basic specific gravity from this study is 0.49 and the weight at 12 percent moisture content is 38 pounds per cubic foot.

Drying and Shrinkage: The lumber air seasons rapidly and easily with little or no degrade. However, material containing tension wood will be subject to warp. Kiln schedule T5- C3 has been suggested for 4/4 stock. A faster schedule was developed that can dry this wood to 7 percent moisture content in 6 to 8 days *(2)*. Shrinkage green to ovendry: radial 3.9 percent; tangential 7.8 percent.

Working Properties: The wood is easy to machine. However, tension wood is sometimes prevalent and this will cause fuzzy grain and burning of saws due to pinching. Takes stains and finishes readily; presents no gluing problems.

Durability: The wood is vulnerable to attack by stain and decay fungi as well as insects.

Preservation: Reported to be treatable, but with no detailed information.

Uses: Plywood, particleboard, fiberboard, carpentry, light construction, furniture components, pulp and paper products, and moldings.

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Summary

Mechanical properties and specific gravity were measured on material taken from five trees of each of seven Columbian wood species—anime, chalviande, cuangare, pulgande, sajo, sande, and tulapueta. Average specific gravity values (green volume, ovendry weight) ranged from 0.313 for cuangare to 0.497 for anime. Variations in mechanical properties between species generally appeared to relate to specific gravity differences. Cuangare and sande had the lowest and highest figures, respectively, for bending strength in the green moisture condition (4,020 and 8,490 lb/in.^{2}), for green modulus of elasticity (1.01 and 1.94 million lb/in.^{2}), and for bending strength and stiffness at the 12 percent moisture condition.

Results for cuangare, sajo, and sande are compared to values previously published. The German DIN procedures appear to provide higher bending strength values but lower values in shear and in modulus of elasticity. As a reference basis, the results for all species are also compared to published values for basswood, balsam poplar, yellow-poplar, sweetgum, and northern red oak, native U.S. species with similar mechanical properties.

Information on drying and shrinkage, working properties, natural durability, treatability, and general characteristics is summarized from world literature. These data, together with the mechanical property information reported, provide a basis for more efficient utilization of these species.

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Table 1.—**Mean, standard deviation, and coefficient of variation of mechanical properties for seven Colombian woods in the green and air dry moisture condition**[1]

Property	Green moisture condition: Mean[2]	Green moisture condition: Standard deviation	Green moisture condition: Coefficient of variation	Air dry moisture condition: Mean[2,3]	Air dry moisture condition: Standard deviation	Air dry moisture condition: Coefficient of variation	Units for means and standard deviations
			Pct			Pct	
ANIME *(Protium spp.)*							
Specific gravity[4]	0.497	0.046	9.23	0.546	0.064	11.7	—
Static bending							
Modulus of rupture	8,178	1,326	16.2	3,869	1,876	13.5	lb/in.^{2}
Modulus of elasticity	1.620	0.267	16.5	2.052	0.328	16.0	10^3 lb/in.^{2}
Compression parallel to grain							
Maximum crushing strength	3,697	696	18.8	7,096	1,001	14.1	lb/in.^{2}
Modulus of elasticity	1.701	0.386	22.7	2.444	0.486	19.9	10^3 lb/in.^{2}
Maximum shearing strength parallel to grain							
Radial	921	150	16.2	1,245	201	16.1	lb/in.^{2}
Tangential	1,247	189	15.2	1,685	182	10.8	lb/in.^{2}
Compression perpendicular to grain							
Crushing strength at proportional limit	275	53.4	19.4	687	128	18.6	lb/in.^{2}
Hardness[5]							
End	731	108	14.8	1,187	220	18.5	lbs
Side	673	127	18.9	920	215	23.3	lbs
CHALVIANDE *(Virola spp.)*							
Specific gravity[4]	0.373	0.036	9.66	0.425	0.044	10.3	—
Static bending							
Modulus of rupture	5,037	1,005	20.0	9,745	1,720	17.6	lb/in.^{2}
Modulus of elasticity	1.397	0.205	14.7	1.916	0.281	14.6	10^3 lb/in.^{2}
Compression parallel to grain							
Maximum crushing strength	2,431	449	18.5	5,649	928	16.4	lb/in.^{2}
Modulus of elasticity	1.708	0.292	17.1	2.[illegible]74	0.378	17.4	10^3 lb/in.^{2}
Maximum shearing strength parallel to grain							
Radial	497	102	20.2	626	128	20.4	lb/in.^{2}
Tangential	723	159	22.0	1,171	236	20.1	lb/in.^{2}
Compression perpendicular to grain							
Crushing strength at proportional limit	134	41.9	31.4	—	—	—	—
Hardness[5]							
End	414	75.5	18.2	628	175	27.8	lbs
Side	342	62.8	18.3	481	117	24.4	lbs

Table 1.—Mean, standard deviation, and coefficient of variation of mechanical properties for seven Colombian woods in the green and air dry moisture condition[1] — con.

Property	Green moisture condition: Mean[2]	Green: Standard deviation	Green: Coefficient of variation	Air dry moisture condition: Mean[2,3]	Air dry: Standard deviation	Air dry: Coefficient of variation	Units for means and standard deviations
			Pct			Pct	
CUANGARE (*Dialyanthera* spp.)							
Specific gravity[4]	0.313	0.072	8.70	0.360	0.026	7.18	—
Static bending							
Modulus of rupture	4,024	657	16.3	7,297	1,115	15.3	lb/in.²
Modulus of elasticity	1.013	0.215	21.3	1.519	0.240	15.8	10³ lb/in.²
Compression parallel to grain							
Maximum crushing strength	2,077	399	19.2	4,763	664	13.9	lb/in.²
Modulus of elasticity	1.209	0.249	20.6	1.695	0.317	18.7	10³ lb/in.²
Maximum shearing strength parallel to grain							
Radial	514	144	28.0	659	92.4	14.0	lb/in.²
Tangential	637	109	17.1	1,002	111	11.1	lb/in.²
Compression perpendicular to grain							
Crushing strength at proportional limit	120	34.0	28.4	177	31.3	17.7	lb/in²
Hardness[5]							
End	300	44.3	14.8	614	76.8	12.5	lbs
Side	235	36.9	15.7	376	63.7	17.0	lbs
PULGANDE (*Dacryodes* spp.)							
Specific gravity[4]	0.428	0.045	10.5	0.460	0.053	11.6	—
Static bending							
Modulus of rupture	7,055	1,089	15.4	11,414	1,374	12.0	lb/in.²
Modulus of elasticity	1.445	0.188	13.0	1.733	0.202	11.7	10³ lb/in.²
Compression parallel to grain							
Maximum crushing strength	3,661	461	12.6	6,395	725	11.3	lb/in.²
Modulus of elasticity	1.645	0.300	18.2	2.020	0.273	13.5	10³ lb/in.²
Maximum shearing strength parallel to grain							
Radial	929	138	14.9	1,365	249	18.3	lb/in.²
Tangential	986	123	12.5	1,488	233	15.7	lb/in.²
Compression perpendicular to grain							
Crushing strength at proportional limit	124	28.1	22.6	618	156	25.3	lb/in²
Hardness[5]							
End	638	116	18.1	889	191	21.4	lbs
Side	519	116	22.4	666	169	25.3	lbs

Table 1.—Mean, standard deviation, and coefficient of variation of mechanical properties for seven Colombian woods in the green and air dry moisture condition[1] — *con.*

Property	Green moisture condition: Mean[2]	Standard deviation	Coefficient of variation	Air dry moisture condition: Mean[2,3]	Standard deviation	Coefficient of variation	Units for means and standard deviations
			Pct			Pct	
SAJO *(Campnosperma panamensis)*							
Specific gravity[4]	0.335	0.019	5.81	0.373	0.021	5.75	—
Static bending							
Modulus of rupture	5,078	374	7.36	8,700	766	8.81	lb/in.^{2}
Modulus of elasticity	1.075	0.124	11.5	1.479	0.097	6.56	10^3 lb/in.^{2}
Compression parallel to grain							
Maximum crushing strength	2,659	308	11.6	5,199	283	5.45	lb/in.^{2}
Modulus of elasticity	1.277	0.169	13.3	1.625	0.114	7.04	10^3 lb/in.^{2}
Maximum shearing strength parallel to grain							
Radial	737	86.3	11.7	965	61.0	6.32	lb/in.^{2}
Tangential	839	96.2	11.5	1,093	128	11.7	lb/in.^{2}
Compression perpendicular to grain							
Crushing strength at proportional limit	140	22.4	16.0	322	42.8	13.3	lb/in^2
Hardness[5]							
End	433	48.1	11.1	613	67.2	11.0	lbs
Side	336	43.8	13.0	425	38.4	9.04	lbs
SANDE *(Brosimum utile)*							
Specific gravity[4]	0.494	0.016	3.19	0.541	0.020	3.69	—
Static bending							
Modulus of rupture	8,493	838	9.87	14,314	1,282	8.96	lb/in.^{2}
Modulus of elasticity	1.941	0.280	14.4	2.386	0.310	13.0	10^3 lb/in.^{2}
Compression parallel to grain							
Maximum crushing strength	4,489	417	9.29	8,225	613	7.46	lb/in.^{2}
Modulus of elasticity	2.318	0.321	13.9	2.803	0.351	12.5	10^3 lb/in.^{2}
Maximum shearing strength parallel to grain							
Radial	929	205	22.1	1,134	135	11.9	lb/in.^{2}
Tangential	1,144	87.4	7.64	1,449	137	9.44	lb/in.^{2}
Compression perpendicular to grain							
Crushing strength at proportional limit	227	35.6	15.7	541	105	19.4	lb/in^2
Hardness[5]							
End	676	43.4	6.42	1,125	134	11.9	lbs
Side	603	42.5	7.06	903	55.8	6.18	lbs

Table 1.—Mean, standard deviation, and coefficient of variation of mechanical properties for seven Colombian woods in the green and air dry moisture condition[1] — con.

Property	Green moisture condition: Mean[2]	Green: Standard deviation	Green: Coefficient of variation	Air dry moisture condition: Mean[2,3]	Air dry: Standard deviation	Air dry: Coefficient of variation	Units for means and standard deviations
			Pct			Pct	
TULAPUETA (*Osteophloeum platyspermum*)							
Specific gravity[4]	0.400	0.055	13.7	0.432	0.060	14.0	—
Static bending							
Modulus of rupture	6,198	1,746	28.2	9,947	2,455	24.7	lb/in.²
Modulus of elasticity	1.381	0.265	19.2	1.661	0.221	13.3	10³ lb/in.²
Compression parallel to grain							
Maximum crushing strength	3,107	964	31.0	5,581	1,174	21.0	lb/in.²
Modulus of elasticity	1,603	0.344	21.5	1.868	0.296	15.8	10³ lb/in.²
Maximum shearing strength parallel to grain							
Radial	659	177	26.9	844	149	17.6	lb/in.²
Tangential	999	235	23.5	1,209	202	16.7	lb/in.²
Compression perpendicular to grain							
Crushing strength at proportional limit	238	152	63.7	391	146	37.3	lb/in²
Hardness[5]							
End	440	187	42.7	632	183	29.0	lbs
Side	496	177	35.6	512	151	29.4	lbs

Table 2.—Specific gravity and mechanical properties of Sajo, Sande, and Cuangare compared to values previously reported for these species[1]

Species	Number of trees	Specific[2] gravity	Static bending: Modulus of rupture	Static bending: Modulus of elasticity	Maximum crushing strength parallel to grain	Shear strength	Compression perpendicular to grain stress at proportional limit	Hardness: End[3]	Hardness: Side[3]
			Lb/in.²	10⁶ lb/in.²	Lb/in.²	Lb/in.²	Lb/in.²	Lb	Lb
GREEN MOISTURE CONDITION									
Cuangare	5	0.313	4,024	1.013	2,077	576	120	300	235
	10	.34	4,100	.970	1,910	600	190	—	—
	5	.349							
Sajo	5	.335	5,078	1.075	2,659	788	140	433	336
	10	.35	5,100	1.210	2,180	710	300	—	—
	5	.348							
Sande	5	.494	8,493	1.941	4,489	1,036	227	676	603
	8	.48	8,600	1.470	3,670	1,040	440	—	—
	5	.445							
12 PERCENT MOISTURE CONTENT									
Cuangare	5	.360	7,297	1.519	4,763	830	177	614	376
	10	—	7,200	1.360	4,080	1,050	380	770	500
	5	—	9,810	1.430	—	650	—	—	360
Sajo	5	.373	8,700	1.479	5,199	1,029	322	613	425
	10	—	9,000	1.520	4,660	1,090	550	880	520
	5	—	10,590	1.400	—	810	—	—	400
Sande	5	.541	14,310	2.386	8,225	1,292	541	1,125	903
	8	—	15,100	1.990	7,180	1,440	720	1,100	810
	5	—	14,680	1.950	—	910	—	—	690

[1] The first line in each data set are results from this investigation; the second are those from Mothershead and Markley *(6)*; the third are values from Lastra et al. *(4)*.
[2] Based upon ovendry weight and volume at test.
[3] Load required to embed a 0.444-inch ball to one-half its diameter.

Table 3.—Average specific gravity and mechanical properties of seven Colombian woods compared to selected species native to the United States

Species	Specific[1] gravity	Static bending: Modulus of rupture	Static bending: Modulus of elasticity	Maximum crushing strength parallel to grain	Shear strength	Compression perpendicular to grain stress at proportional limit	Hardness: End[2]	Hardness: Side[2]
		Lb/in.^{2}	10^6 lb/in.^{2}	Lb/in.^{2}	Lb/in.^{2}	Lb/in.^{2}	Lb	Lb
GREEN MOISTURE CONDITION								
(Colombian)								
Cuangare	0.313	4,020	1.01	2,080	576	120	300	235
Sajo	.335	5,080	1.07	2,660	788	140	433	336
Chalviande	.373	5,040	1.40	2,430	610	134	414	342
Tulapueta	.400	6,200	1.38	3,110	829	238	440	496
Pulgande	.428	7,050	1.44	3,360	958	124	638	519
Sande	.494	8,490	1.94	4,490	1,040	227	676	603
Anime	.497	8,180	1.62	3,700	1,080	275	731	673
(U.S.)[3]								
Basswood	.32	5,000	1.04	2,220	600	170	—	250
Balsam poplar	.31	3,900	.75	1,690	500	140	—	—
Yellow-poplar	.40	6,000	1.22	2,660	790	270	—	440
Sweetgum	.46	7,100	1.20	3,040	990	370	—	600
Northern red oak	.56	8,300	1.35	3,440	1,210	610	—	1,000
12 PERCENT MOISTURE CONTENT								
(Colombian)								
Cuangare	.360	7,300	1.52	4,760	830	177	614	376
Sajo	.373	8,700	1.48	5,200	1,030	322	613	425
Chalviande	.425	9,740	1.92	5,650	898	—	628	481
Tulapueta	.432	9,950	1.66	5,580	1,030	391	632	512
Pulgande	.460	11,400	1.73	6,390	1,430	618	889	666
Sande	.541	14,300	2.39	8,220	1,290	541	1,120	903
Anime	.546	13,900	2.05	7,100	1,460	687	1,190	920
(U.S.)[3]								
Basswood	.37	8,700	1.46	4,730	990	370	—	410
Balsam poplar	.34	6,800	1.10	4,020	790	300	—	—
Yellow-poplar	.42	10,100	1.58	5,540	1,190	500	—	540
Sweetgum	.52	12,500	1.64	6,320	1,600	620	—	850
Northern red oak	.63	14,300	1.82	6,760	1,780	1,010	—	1,290

[1] Based upon ovendry weight and volume at test.
[2] Load required to embed a 0.444- inch ball to one-half its diameter.
[3] Values for U.S. species from *(7)*.

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